MAJOR ARTICLE

Tri-County Comprehensive Assessment of Risk Factors for Sporadic Reportable Bacterial Enteric Infection in Children

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(See the editorial commentary by Jones, on pages 465–6.)

Background. The aim of this study was to determine risk factors for childhood sporadic reportable enteric infection (REI) caused by bacteria, specifically *Campylobacter, Salmonella, Escherichia coli* O157, or *Shigella* (REI-B).

Methods. Matched case-control study. Case patients aged <19 years who were reported to 3 Washington State county health departments and matched control subjects were interviewed from November 2003-November 2005. Matched odds ratios (ORs) were calculated by using conditional logistic regression. Population attributable risk percentages were calculated for exposures associated with infection.

Results. Two hundred ninety-six case patients were matched to 580 control subjects. Aquatic recreation was the most important factor associated with all REI-Bs studied (beach water exposure [OR for *Salmonella* infection, 28.3 {CI, 7.2–112.2}; OR for *Shigella* infection, 14.5 {CI 1.5–141.0} or any recreational water exposure [OR for *Campylobacter* infection, 2.7 {CI, 1.5–4.8}; OR for *Escherichia coli* O157 infection, 7.4 {CI, 2.1–26.1}]). Suboptimal kitchen hygiene after preparation of raw meat or chicken (OR, 7.1 [CI, 2.1–24.1]) and consumption of food from restaurants were additional risks for *Campylobacter* infection. Infection with *Salmonella* was associated with the use of private wells as sources of drinking water (OR, 6.5 [CI, 1.4–29.7]), and the use of residential septic systems was a risk for both *Salmonella* (OR, 3.2 [CI, 1.3–7.8]) and *E. coli* (OR, 5.7 [CI, 1.2–27.2]) O157 infection.

Conclusions. Overall, non-food exposures were as important as food-related exposures with regard to their contributions to the proportion of cases. Infection prevention efforts should address kitchen hygiene practices and non-food exposures, such as recreational water exposure, in addition to food-consumption risks.

Approximately 100,000 infections caused by *Campylobacter, Salmonella, Escherichia coli* O157, and *Shigella* are reported annually to local health departments (LHDs) in the United States [1], making them the most common reportable enteric infections (REIs) caused by bacteria (REI-B). Most REI-Bs occur among children [2–4], and it is estimated that dozens of additional infections occur for each case reported [1]. Outbreaks of REI-B represent ongoing public health problems that receive considerable attention in the media and scientific literature [5–11]. However, current data suggest that up to 90% of REI-B is sporadic, that is, not outbreak related [1]. While specific foods are the transmission vehicles most often identified in outbreak investigations [6–8, 11, 12], food preparation and kitchen hygiene practices, as well as non-food vehicles (e.g., exposure to water and/or animals), might play more important roles than particular foods per se (e.g., undercooked meat) in the transmission of sporadic disease [13–19].

Because of the higher incidence of REI-B among children, limited data on the modes by which non-outbreak REI-Bs are acquired, and the possibility that infection control lessons learned from outbreaks might not apply

EXHIBIT

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to a great number of sporadic infections, we conducted a prospective case-control study to identify associations between sporadic childhood REI-B and a diverse and comprehensive panel of plausible exposures. Our overall goal was to identify the modifiable risk factors associated with the greatest proportion of cases.

METHODS

Study design and population. We performed a matched case-control study of selected REI-Bs among children in King, Whatcom, and Yakima Counties in Washington. A case patient was defined as a resident of these counties younger than 19 years who had laboratory-confirmed *Campylobacter, E. coli* O157, *Salmonella,* or *Shigella* infection, reported to a LHD during a 24-month period that commenced in November 2003. These counties had combined 2005 populations of ~490,000 individuals <19 years of age [20]. Exclusion criteria were undefined onset of illness, immigration to the United States or Canada in the 6 months before illness onset, travel outside either of these countries during the exposure period, belonging to a recognized cluster of illness involving >1 household or belonging to a cluster within a single household and not being the individual who had the earliest onset of symptoms. The following pathogen-specific exposure periods were based on published data: *Campylobacter,* 2–7 days; *E. coli* O157, 2–8 days; *Salmonella,* 6 h–5 days; *Shigella,* 1–4 days [2, 21, 22].

Control subjects. Potential control subjects were identified at family practice and pediatric clinics in the study area by prospective distribution of multilingual printed materials that explained study goals. Parents who were willing to enroll their children as potential control subjects were asked to provide basic demographic characteristics and contact information. For each case patient interviewed, we identified and then contacted the 2 best control subject matches from the pool of potential control subjects by using a computer algorithm that matched age (closest ± 50%, up to 19 years of age), zip code (same or adjacent zip code, to reduce confounding by socioeconomic and/or demographic characteristics), and sex (when possible). Control subject exclusion criteria included the same travel and residency restrictions as for case patients, as well as diarrhea in the preceding 30 days, a sibling chosen as a control subject for the same case patient, or previous study participation.

Questionnaires and interviews. We developed standardized, pathogen-specific questionnaires that addressed domestic travel; dining venues; food handling, preparation, and consumption practices; water supply and sanitation; animal and recreational water exposures; and demographic characteristics (table 1, which appears only in the electronic version of the *Journal*). All interviewers were trained in the use of the survey instrument. After determining eligibility and obtaining consent, the LHD (for case patients, to maintain confidentiality) or 1 of 2 research assistants (for control subjects) interviewed the caregiver most familiar with the food and activity histories of the participant. Participants >9 years old were encouraged to participate in interviews. Case patients were interviewed as promptly as possible after their infection was reported; control subjects were contacted as soon as possible after the case patient was interviewed, but always within 4 months to maintain temporal matching. Case patients and control subjects were asked about the same exposure interval, counting back from the onset of illness and the date of the interview, respectively. The study was approved by the Children's Hospital and Regional Medical Center and Washington University institutional review boards.

Table 1. Exposure variables evaluated in pathogen-specific questionnaires administered to case patients and control subjects.

The table is available in its entirety in the online edition of *The Journal of Infectious Diseases.*

Statistical analysis. We performed descriptive and pathogen-specific univariate and multivariate analyses using Stata (version 9; Statacorp). We used conditional logistic regression for univariate and multivariate analyses of all surveyed exposures to calculate matched odds ratios (ORs) and 95% confidence intervals (CIs). To adjust for confounding by demographic and socioeconomic factors, the multivariate analysis included those variables associated with disease status, including matching variables if there was residual confounding. We then further adjusted for exposure variables that were associated with both disease and exposures of interest. We only present these latter estimates if they meaningfully differed from those models solely adjusted for socioeconomic status (SES) and demographic characteristics. For variables with statistically significant associations ($P < .05$) in the final regression models, we calculated population attributable risk percentages (PAR%) and 95% CIs adjusted for SES and demographic variables by bootstrap methodology [23] to estimate the magnitude of each factor's relative contribution to disease occurrence. It should be noted that PAR% sums can exceed 100% because the cumulative effects of multiple factors are not necessarily additive [24].

RESULTS

Study population

During the study period, 546 pediatric REI-Bs were reported; 237 were due to *Campylobacter,* 190 to *Salmonella,* 67 to *Shigella,* and 52 to *E. coli* O157. Of 546 patients with REI-B, 61 (11.2%), 50 (9.2%), and 31 (5.7%) patients were excluded because they had traveled outside the United States or Canada, were part of recognized outbreaks involving >1 household, or for other reasons, respectively (figure 1). Of the 404 remaining case patients, 296 (73.3%) participated, including 151 patients with *Campy-*

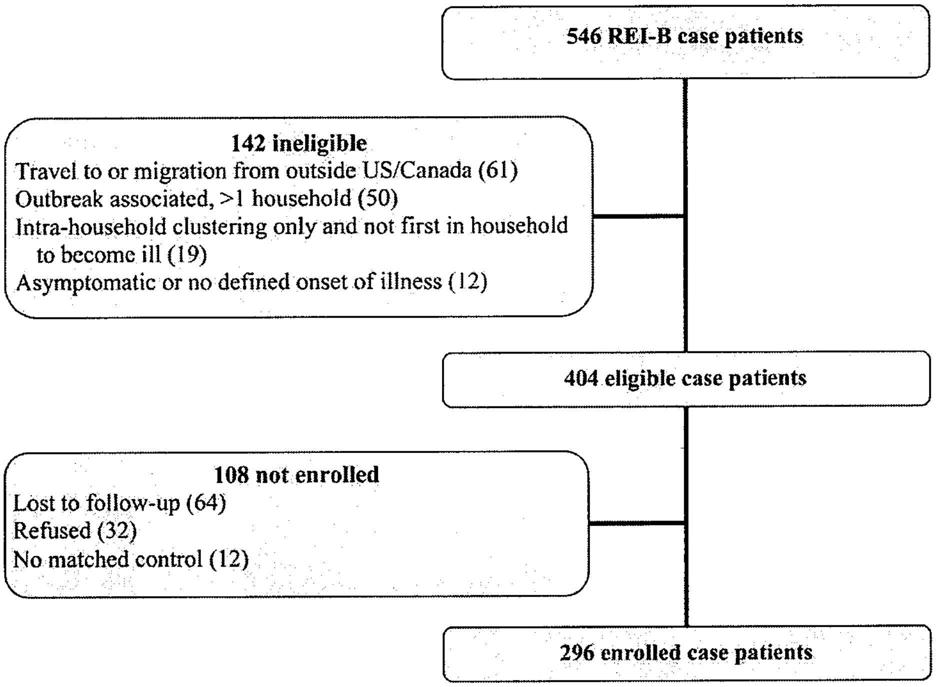

Figure 1. Study enrollment of case patients with laboratory-confirmed reportable enteric infection caused by bacteria (REI-B). Numbers in parentheses are no. of participants. See Methods for details about exclusion criteria.

lobacter infection, 86 with *Salmonella* infection, 39 with *E. coli* O157 infection, and 20 with *Shigella* infection. Ineligible and nonparticipating case patients were less likely to be white but otherwise resembled participants (table 2, which appears only in the electronic version of the *Journal*). A mean of 1.97 control subjects participated per case patient (SD, 0.40; range, 1–4 patients). The median time from onset of illness to case patient interview was 11 days (75th percentile, 19 days; 90th percentile, 25 days), and the median time from case patient interview to control subject interview was 27 days (75th percentile, 45 days; 90th percentile, 69 days).

The 296 case patients and 580 matched control subjects were similar in terms of sex, eligibility for low-income services, ethnicity, housing type, and urban or rural residence, but case patients were less likely to be white, overall had parents with a lower level of education, had smaller household sizes, and were more likely to be the only child in a household (table 3, which appears only in the electronic version of the *Journal*). Also, despite age-matching, residual age differences between case patients and control subjects remained (0.2 years aggregate median difference).

Table 2. Demographic characteristics of participating and nonparticipating case patients.

The table is available in its entirety in the online edition of *The Journal of Infectious Diseases*.

Risk factor analysis

Various exposures were associated with each REI-B studied. ORs for dichotomous and categorical variables, both unadjusted and adjusted for SES and demographic variables associated with disease status (as noted in table 4 and table 3, which appears only in the electronic version of the *Journal*), with P values $<.05$ in the adjusted models are presented in tables 4 and 5, respectively. All point estimates discussed below refer to adjusted estimates. PAR% adjusted for SES and demographic variables are presented in table 6.

Travel and commercial food venues. Domestic travel (defined as an overnight stay away from home within the United States or Canada) was associated with *Campylobacter* infection (table 4; OR, 2.5 [CI, 1.4–4.6]) and *E. coli* O157 infection (OR, 6.8 [CI, 1.6–28.5]). Consumption of foods from mobile food stands and fast-food or table-service restaurants were risk factors for *Campylobacter* infection. Eating food from self-serve buffets, mobile stands, or table-service restaurants was associated with *E. coli* O157 infection.

Table 3. Demographic characteristics of participating case patients and control subjects, according to pathogen infecting the case patient.

The table is available in its entirety in the online edition of *The Journal of Infectious Diseases*.

Table 4. Univariate and multivariate analysis of selected risk factors for sporadic reportable enteric infection caused by bacteria.

Risk factor	Univariate OR (95% CI)	Multivariate OR (95% CI)[a]
Travel		
Domestic overnight travel	C: 1.8 (1.0–3.1) E: 3.6 (1.2–10.7)	C: 2.5 (1.4–4.6) E: 6.8 (1.6–28.5)
Commercial food venue		
Ate food from a mobile food stand	C: 4.8 (1.9–11.8) E: 6.0 (0.6–59.4)	C: 4.4 (1.7–11.5) E: 21.4 (2.7–171.1)
Ate food from a table-service restaurant	E: 2.5 (1.1–5.7)	E: 3.7 (1.1–12.5)
Increased frequency of eating at table-service restaurants	C: 3.4 (1.4–8.5)	C: 4.2 (1.6–11.3)
Ate food from a fast-food restaurant	C: 1.4 (0.9–2.1)	C: 1.7 (1.0–2.8)
Ate food from a self-serve buffet	E: 1.4 (0.1–18.5)	E: 9.9 (1.3–73.3)
Home food handling and preparation		
Touched raw meat or poultry	C: 3.7 (1.6–8.8)	C: 3.79 (1.5–9.3)
Touched raw beef	C: 3.2 (1.1–9.0)	C: 3.9 (1.8–14.3)
Consumed specific foods prepared from raw state at home		
Chicken	C: 2.4 (1.4–4.0)	C: 2.3 (1.3–4.3)
Beef	C: 2.4 (1.4–3.8)	C: 2.2 (1.3–3.6)
Pork	C: 2.0 (1.2–3.3) Sm: 2.1 (1.1–4.4)	C: 1.7 (1.0–2.9) Sm: 2.0 (1.0–4.1)
Shrimp	Sm: 3.6 (1.5–8.8)	Sm: 2.7 (1.1–6.7)
Consumed specific foods—any venue		
Unpasteurized milk [b]	C: 3.0 (0.5–18.1)	C: 4.3 (1.0–18.1)
Unheated dried meat	C: 2.0 (1.1–3.5)	C: 2.2 (1.2–4.1)
Eggs	C: 1.7 (1.1–2.6)	C: 1.7 (1.0–2.7)
Raw cilantro	C: 4.5 (2.5–8.4) Sh: 13.4 (1.8–99.5)	C: 5.3 (2.6–10.9) Sh: 45.0 (7.9–256.5)
Raw basil	C: 4.7 (1.5–14.7)	C: 8.3 (2.0–35.2)
Raw sprouts	Sm: 5.8 (0.6–60.6)	Sm: 7.7 (1.2–47.7)
Sprouts in household, but did not eat any	Sm: 3.0 (1.1–8.0)	Sm: 3.2 (1.2–8.1)
Raw vegetables	Sh: 6.3 (1.3–32.1) Sm: 0.3 (0.2–0.6)	Sh: 6.4 (1.3–31.3) Sm: 0.4 (0.2–0.8)
Organic produce	Sm: 0.4 (0.2–1.0)	Sm: 0.4 (0.1–0.9)
Fresh lettuce or spinach from sealed retail packages, among those who ate fresh lettuce or spinach	Sm: 3.2 (1.0–9.8)	Sm: 26.7 (1.0–723.9)
Animals		
Livestock at home	C: 2.4 (1.0–5.6)	C: 3.1 (1.3–7.5)
Poultry at home	C: 3.3 (1.5–7.5)	C: 3.3 (1.3–8.2)
Had direct contact with livestock or poultry at home	C: 3.5 (1.7–7.1)	C: 4.3 (2.0–9.2)
Visited place with farm animals[b]	C: 2.1 (1.2–3.6)	C: 2.7 (1.5–4.9)
Had direct contact with livestock or poultry outside the home	C: 2.3 (1.3–4.2)	C: 2.8 (1.5–5.4)
Direct contact with fresh manure fertilizer	C: 2.0 (0.7–5.5)	C: 3.9 (1.3–11.7)
Puppy at home	C: 2.3 (1.1–4.8)	C: 2.2 (1.0–4.9)
Amphibian or reptile at home	Sm: 2.4 (1.0–5.7)	Sm: 2.6 (1.0–6.9)
Water and sanitation		
Drank untreated surface water directly from source	C: 14.3 (3.2–64.6)	C: 14.5 (3.1–67.7)
Drank water from garden hose	C: 4.4 (2.2–8.6)	C: 4.1 (2.0–8.8)
Dishwasher use	E: 0.5 (0.2–1.3)	E: 0.3 (0.1–0.9)
Private well as home water source	Sm: 7.3 (1.4–36.7)	Sm: 6.5 (1.4–29.7)
Septic system for home sanitation	Sm: 1.9 (0.8–4.2) E: 2.3 (0.9–6.3)	Sm: 3.2 (1.3–7.8) E: 5.7 (1.2–27.2)
Recreational water activity		
Any	C: 2.2 (1.3–3.8) E: 3.4 (1.4–8.6)	C: 2.7 (1.5–4.8) E: 7.4 (2.1–26.1)

(continued)

Table 4. *(Continued.)*

Risk factor	Univariate OR (95% CI)	Multivariate OR (95% CI)[a]
Play in "kiddie" or wading pool	C: 3.7 (1.8–7.6)	C: 3.1 (1.4–6.7)
Play in natural source of water, either fresh or saltwater	C: 3.4 (1.6–7.4) Sm: 7.0 (2.3–21.6) Sh: 12.3 (1.2–123.8)	C: 3.4 (1.4–8.4) Sm: 28.3 (7.2–112.2) Sh: 14.5 (1.5–141.0)
Sick contacts and medications		
Contact with person with diarrheal illness	C: 2.3 (1.1–4.9) Sh: 7.3 (0.9–56.5)	C: 2.6 (1.2–5.7) Sh: 7.3 (1.2–43.2)
Took antacids or acid suppression therapy	Sm: 4.6 (1.5–14.5)	Sm: 3.2 (1.1–9.7)

NOTE. Table presents exposure associations significant to the .05 level in univariate analyses, and all exposures significant to the .05 level in the multivariate analyses. C, *Campylobacter;* CI, confidence interval; E, *Escherichia coli* O157; Sh, *Shigella*; Sm, *Salmonella*; OR, odds ratio.

[a] Multivariate ORs were adjusted for the socioeconomic status and demographic variables associated with infection due to individual pathogens, which were as follows: C—age, race, housing type, and parental education level; Sm—age, race, and no. of children in household; E—age, parental education level, and no. of children in household; Sh—age and housing type. There was a statistically significant association between Hispanic ethnicity and shigellosis, however, we were unable to adjust for ethnicity due to convergence issues as 67% and 100% of control subjects and case patients, respectively, were of Hispanic ethnicity.

[b] The ORs for these exposure variables approached the null value of 1 when further adjusted for other potentially confounding exposure variables. Hence population attributable risk percentages were not calculated for these variables.

Food handling and preparation practices. *Campylobacter* infection was associated with raw meat and poultry exposures, including handling of these foods (table 4), in-home practices related to thawing these foods, and cleaning methods used for the surfaces (e.g., cutting boards, sinks, or counters) on which these items were prepared (table 5). Among participants from households that prepared raw meat or poultry, there was no significant difference between the reference group (who placed the meat directly in a cooking pan without allowing the meat to touch other preparation surfaces) and those who bleached the preparation surfaces or washed them in a dishwasher. The risk was highest in households where surfaces were washed with soap and water only (OR compared to reference group, 3.0 [CI, 1.2–7.6]) or merely wiped following use (OR compared to reference group, 7.1 [CI, 2.1–24.1]). Risk did not vary between those who used plastic cutting boards and those who used wooden cutting boards. Food handling and preparation practices were not significantly associated with *Salmonella* or *E. coli* O157 infection (data not shown).

Food consumption. Consumption of foods prepared at home from raw chicken, beef, or pork was associated with *Campylobacter* infection, whereas consumption of pork or

Table 5. Univariate and multivariate analysis of categorical variables associated with *Campylobacter* infection.

Categorical variable	Unadjusted OR (95% CI)[a]	P	Adjusted OR (95% CI)[a]	P
Clean-up practices for surfaces used to prepare raw poultry or meat				
No preparation—raw meat placed directly into pan or used disposable board	Reference		Reference	
Bleach or dishwasher	1.5 (0.7–3.4)	.009	1.8 (0.7–4.7)	.008
Washed with soap	3.0 (1.3–6.8)		3.0 (1.2–7.6)	
Rinsed or wiped	6.4 (2.3–17.8)		7.1 (2.1–24.1)	
Methods for thawing				
Raw frozen poultry				
Cooked frozen or thawed in refrigerator or microwave	Reference		Reference	
Thawed in water and/or in sink	1.5 (0.5–4.4)	.029	0.6 (0.2–1.9)	.053
Thawed at room temperature	4.2 (1.4–12.9)		3.1 (1.0–10.1)	
Raw frozen meat				
Cooked frozen or thawed in refrigerator or microwave	Reference		Reference	
Thawed in water and/or in sink	2.8 (0.9–8.2)	.062	1.4 (0.4–5.5)	.22
Thawed at room temperature	4.3 (1.1–16.5)		4.0 (0.8–19.8)	

NOTE. Multivariate odds ratios (ORs) adjusted for age, race, housing type, and parental education level. Exposures were not ascertained for *Shigella* infection, and were not associated with *Salmonella* or *Escherichia coli* O157 infection. CI, confidence intervals.

[a] ORs are for comparison with reference group.

Table 6. Population attributable risk percentages for sporadic reportable enteric infection caused by bacteria.

Risk factor	Population attributable risk percentage (95% CI)
Travel	
Domestic overnight travel	C: 11.4 (4.0–21.4) E: 31.4 (14.6–51.3)
Commercial food venue	
Ate food from a mobile food stand	C: 9.2 (3.4–15.5) E: 9.8 (-8.3–20.9)
Ate food from a table-service restaurant	C: 9.0 (-3.7–21.5) E: 37.3 (15.8–64.3)
Ate food from a fast-food restaurant	C: 26.6 (2.0–52.1)
Ate food from a self-serve buffet	E: 4.6 (0.0–13.2)
Home food consumption, handling, and preparation	
Clean-up methods for raw meat and/or poultry preparation surfaces[a]	C: 36.4 (18.8–57.9)[b]
Touched raw chicken	C: 8.7 (3.1–13.6)
Ate beef prepared from raw state	C: 38.7 (22.3–59.1)
Ate chicken prepared from raw state	C: 42.4 (18.3–66.8)
Ate pork prepared from raw state	C: 12.4 (0.9–26.0) Sm: 18.4 (3.3–35.5)
Ate shrimp prepared from raw state	Sm: 10.4 (-0.1–21.5)
Consumed specific foods—any venue	
Raw basil	C: 5.9 (1.7–10.2)
Raw cilantro	C: 22.9 (14.9–33.9) Sh: 36.0 (10.9–55.6)
Raw sprouts	Sm: 3.1 (-0.3–8.2)
Unheated dried meat	C: 9.8 (2.9–20.0)
Animals	
Livestock at home	C: 6.7 (1.4–13.8)
Poultry at home	C: 10.1 (3.1–18.2)
Had direct contact with livestock or poultry at home	C: 11.3 (6.2–19.5)
Direct contact with fresh manure fertilizer	C: 4.0 (0.7–8.8)
Water exposure and sanitation	
Drank untreated surface water directly from source	C: 8.7 (4.8–14.8)
Drank water from garden hose	C: 15.3 (7.9–24.2)
Private well used for home water source	Sm: 11.0 (4.2–20.6)
Septic system used for home sanitation	Sm: 16.7 (4.7–30.1) E: 32.6 (-2.0–55.2)
Any recreational water activity	C: 22.5 (11.4–35.6) E: 44.4 (25.7–67.4)
Recreational water play in "kiddie" or wading pool	C: 14.2 (6.1–22.9)
Recreational water play in natural source of water, either fresh or saltwater	C: 10.8 (3.6–19.4) Sm: 20.7 (12.8–31.4) Sh: 27.9 (4.5–47.4)
Sick contacts and medications	
Contact with person with diarrheal illness	C: 8.0 (1.4–17.4) Sh: 14.4 (0.4–35.3)
Took antacids or acid suppression therapy	Sm: 8.1 (0.6–16.1)

NOTE. C, *Campylobacter;* Sm, *Salmonella;* E, *Escherichia coli* O157; Sh, *Shigella.*

[a] Data on clean-up methods were only collected for people who prepared raw meat. The population attributable risk percentage (PAR%) represents the percentage of disease that would be prevented by changing clean-up methods among those who prepared raw meat in the household.

[b] This categorical variable is presented as a dichotomized variable for PAR% calculation purposes. The risk represents comparison between the exposed group—those who washed with soap, rinsed, or wiped the surfaces vs. the reference—those who disinfected with bleach, washed in dishwasher, used a disposable surface, or placed raw meat in a cooking pan without allowing it to touch other preparation surfaces.

shrimp prepared from raw states at home was a risk factor for *Salmonella* infection. Consumption of unpasteurized milk was associated with *Campylobacter* infection, however, the OR approached 1 when potentially confounding exposure variables (e.g., farm animal contact) were included in the model. Consumption of raw herbs, particularly cilantro, was a risk for *Campylobacter* infection (OR for cilantro, 5.3 [CI, 2.6–10.9]) and *Shigella* infection (OR for cilantro, 45.0 [CI, 7.9–256.5]). Raw sprout consumption and simply having sprouts in the home without consumption were risk factors for *Salmonella* infection (OR, 7.7 [CI, 1.2–47.7] and 3.2 [CI, 1.2–8.1], respectively).

Eating raw vegetables was associated with a lower risk of *Salmonella* infection. This association was seen among those who ate meat and poultry, as well as among those who consumed a vegetarian diet. Consumption of raw organic vegetables was also potentially protective, even when assessed only among those who consumed raw vegetables. However, among those who ate raw spinach or lettuce, consumption of these products from sealed retail bags was associated with *Salmonella* infection. *E. coli* O157 infection was not associated with any specific foods—including beef, ground or otherwise—prepared at commercial or home venues.

Animals. The presence of farm animals, especially poultry, at home properties was significantly associated with *Campylobacter* infection (OR for poultry, 3.3 [CI, 1.3–8.2]). Approximately half of the participants who had livestock on their property also had poultry and vice versa; this correlation precluded adjustment for these variables. Exposure to livestock and poultry away from the home property was not a risk among participants who did not live on property with such animals.

Water and domestic waste system exposures. Drinking untreated water from a lake, stream, river, or garden hose was a risk for *Campylobacter* infection. Dishwasher use was inversely associated with *E. coli* O157 infection.

Salmonella infection was associated with the use of a private well as a home drinking water source (OR, 6.5 [CI, 1.4–29.7]). Furthermore, *Salmonella* and *E. coli* O157 infections were both associated with the use of a septic system for home wastewater disposal (OR, 3.2 [CI, 1.3–7.8] and 5.7 [CI, 1.2–27.2], respectively), though only 1 participant (a case patient) reported a known septic system failure.

Recreational water activity. Aquatic recreation activities were associated with and contributed a high proportion of cases for each REI-B (table 6). For example, playing or swimming in natural sources of water (either fresh or saltwater) was strongly related to *Campylobacter* infection (OR, 3.4 [CI, 1.4–8.4]; PAR%, 10.8% [CI, 3.6%–19.4%]), *Salmonella* infection (OR, 28.3 [CI, 7.2–112.2]; PAR%, 20.7% [CI, 12.8%–31.4%]), and *Shigella* infection (OR, 14.5 [CI, 1.5–141.0]; PAR%, 27.9% [CI, 4.5%–47.4%]), but not *E. coli* O157 infection. However, recreational water exposure in general (e.g., playing in beach water, in a pool, and in backyard "kiddie" pools) was associated with a 7-fold increased risk of *E. coli* O157 infection (PAR%, 44.4% [CI, 25.7%–67.4%]).

Breast-feeding, hygiene, and ill contacts. Illnesses were not associated with frequency of hand washing, exposure to individuals using diapers, the use of antibiotic soaps or alcohol-based gels, or day care attendance. A lack of association with day care attendance was also observed in various subanalyses that were restricted by age, size of child-care facilities, attendance of children in diapers, and informal and/or unlicensed places of care. A history of breast-feeding was associated with a 50% reduction in the odds of infection with *Salmonella* but the association was not statistically significant (data not shown; OR, 0.5 [CI, 0.2–1.1]).

Campylobacter and *Shigella* infections were associated with contact with another person who had had diarrhea, but without laboratory diagnosis of the REI-B. A separate sensitivity analysis that eliminated case patients and control subjects who had had such contacts from the model substantially reduced matched odds ratios and resulted in confidence intervals spanning 1.0 for all other exposure variables for *Shigella* (data not shown). No substantial changes in point estimates or confidence intervals resulted from the *Campylobacter* sensitivity analysis.

DISCUSSION

This study has various implications. Most notably, non-food transmission vehicles appeared to be as important as food exposures in the transmission of the enteric infections examined in this study.

In particular, water used for recreational swimming or playing contributed a leading proportion of all REI-Bs. Although recreational water exposure has been implicated in many REI-B outbreaks [10, 25, 26] and beach water (without known contamination) has been identified as a risk for nonspecific diarrheal illnesses [27, 28], this is the first study to identify this association with sporadic microbiologically confirmed REI-Bs in the United States and the apparent magnitude of this association was surprisingly large. Most other studies of sporadic REI-Bs have not examined recreational water exposure, and those that did have not identified such associations [29, 30]. Swimming in beach water has been identified as a risk factor for enterohemorrhagic *E. coli* infection (including, but not specifically limited to, infection with *E. coli* O157) and *Campylobacter* infection in Germany and Finland, respectively [17, 18]. Recreational water exposure is a plausible and potentially important risk factor for infection and merits further investigation.

We identified other non-food associations, some of which corroborate other studies and others that are novel associations in the context of sporadic infection. For example, the risk observed here of sporadic *Campylobacter* infection as a result of drinking untreated surface water is in agreement with other reports [14–16], but the use of private well water and the use of septic systems have not been previously reported to be associated with sporadic infection. Our data also refine previously reported associations. For example, animal exposure as a risk for *Campylobacter* infection in our study was limited to children who had animals at their residence. Attention has focused on pathogen transmission in public petting zoos [5, 9, 31–34], and recommendations to mitigate risk in these settings have been disseminated [35]. However, a different focus might be necessary for people living with such animals.

Some food-related exposures warrant comment. Sprouts and cilantro, recognized transmission vehicles in outbreaks [7, 8, 36–38], were demonstrated to be associated with sporadic *Salmonella* and *Campylobacter* infection, respectively, but only cilantro contributed to disease burden. Suboptimal kitchen hygiene practices (i.e., not using bleach or dishwashers) after preparation of raw meat and poultry contributed an important proportion of *Campylobacter* infections, similar to recent findings from France [13]. Handling practices for raw poultry and the consumption of meat or poultry prepared from raw states at home also contributed to the incidence of *Campylobacter* infection.

Eating foods from fast-food and table-service restaurants contributed especially to the incidence of *Campylobacter* and *E. coli* O157 infection (table 6), respectively, as has been previously reported [19, 30, 39]. Interestingly, the risk of *Campylobacter* and *E. coli* O157 infection associated with domestic travel did not appear to be related to eating food from commercial venues, as the risk was not modified by adjusting for any of the restaurant type exposures. Perhaps this risk relates to hygiene lapses during family travel.

Our data also suggest a possible protective food association. Vegetable consumption in general was associated with lowered risk of *Salmonella* infection, an effect that has been reported for *E. coli* O157 [30, 40] and *Campylobacter* [16]. However, the association is complex; consuming fresh lettuce or spinach that came from sealed retail bags was associated with an increased risk of *Salmonella* infection among those who ate fresh lettuce or spinach. This hazard is exemplified by recent outbreaks of *E. coli* O157 infection and *Salmonella* infection caused by bagged, prewashed fresh produce in the United States and the United Kingdom, respectively [6, 12]. While contaminated produce is an important vehicle of transmission for enteric pathogens, other studies have also pointed out the overall benefit of a diet that includes vegetables. The mechanisms that mediate this effect appear to extend beyond the mere replacement of potentially riskier foods (e.g., those of animal origin) with vegetables, and may rather result from the benefits of a diet that is diverse and provides protective micronutrients [16, 30, 40].

Interestingly, we did not find that chicken or egg consumption increased the risk for infection with *Salmonella,* despite reports of such associations with sporadic infection [41, 42]. It is possible that subgroups of *Salmonella* might have vehicle-specific risks that were not discernible because of limited numbers for each serotype and/or differences in prevalence of serotypes associated with such foods in our study area. Also, despite oft-cited associations between ground beef consumption and *E. coli* O157 infection [30, 40, 43, 44], our finding that there was no association is consistent with reports of reduced proportions of recent sporadic cases associated with ground beef exposure [30]. This decline might be related to industry and consumer interventions subsequent to highly publicized outbreaks [45] and to regulatory changes.

The lack of association between hand-washing practices and day care attendance and risk of infection was also unexpected. The possibility exists that these risk factors have been mitigated by regulations at child-care facilities and by education; however, further study is necessary to verify the absence of association.

This study has several limitations. We relied on self-reported behaviors, which do not always reflect actual practices, particularly when the practices are suspected to be associated with infection; however, this limitation is inherent in interview-garnered data. Despite efforts to minimize differences, different interviewers could have introduced biases. Findings from our tri-county study area might not be generalizable to broader populations. Despite our attempts to control for seasonal exposures by interviewing control subjects as soon as possible after case patients were identified, the interval between case patient and control subject interviews might have skewed results pertaining to season-dependent risks. However, a subanalysis limited only to case-control pairs who were interviewed <2 months apart did not alter study findings (data not shown). The voluntary control subjects were not a probability sample of the study base. Sample sizes were insufficient to permit in-depth risk factor–pathogen associations, particularly for very common or uncommon exposures. Zip code matching might underestimate risks related to geography, such as drinking water supply, sanitation sources, and animal exposure. It is difficult to completely measure and therefore adjust for all SES characteristics that could confound associations. Associations with *Shigella* infection should be noted with caution, as we could not adjust for differences in Hispanic ethnicity between *Shigella* case patients and control subjects because of model convergence issues.

Despite these limitations, our tri-county study of childhood REI-Bs adds important information about the epidemiology of sporadic REI-Bs, which are much more common than outbreak-related cases. Similar studies have examined broader geographic and age distributions, but risks specific to more defined populations might have been obscured. Our data were also restricted to domestically acquired infection; many studies have previously documented the risk associated with foreign travel [2, 19, 46–50]. These age, travel, and geographic eligibility boundaries likely explain differences between some of our point estimates, particularly PAR%, and those of other studies. The convergence of associations with data from other studies that involved populations more diverse in age and geographical location, such as FoodNet [19, 30, 39], a multistate sporadic REI-B study network, and a recent countrywide study in France [13] strengthen the validity of these findings. Associations corroborated in this study include the consumption of table-service restaurant food and infection with *E. coli* O157 and *Campylobacter;* and the association of chicken prepared at home, drinking untreated surface water, and poor kitchen hygiene with *Campylobacter* infection [13, 16, 19, 30, 39].

In summary, this study of risks related to sporadic childhood REI-Bs provides a framework in which to consider interventions that might reduce REI-B incidence by weighing relative risks against frequencies of exposures via PAR% calculations. These data suggest that non-food exposures pose risks that are comparable in magnitude to those of food exposures. Moreover, kitchen hygiene may play as important a role as the actual consumption of specific foods. Interventions should focus on risks that, if confirmed, make a large contribution to disease incidence (i.e., those with high PAR%). In contrast, control of "high-risk" (and often high-profile) but low-prevalence exposures (e.g., consumption of sprouts) might have relatively little overall benefit. Interventions focused on safe recreational water, enhanced access to municipal water and sanitation systems, food-handling education, and improved safety of food sold at fast-food and table-service restaurants might more effectively and rapidly reduce the incidence of domestically acquired REI-Bs.

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